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Description of the Ballen2021 data set

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Abstract. The data set *Ballen2021* concerns mainly electrical supply and demand on the Ballen marina, Samso, Denmark. The data set spans the year 2021 divided into time steps of one hour. The purpose is to simulate the operation of a smart energy system. For example, to use the data to develop a scheduling algorithm, which utilizes the available solar energy maximally. The energy system involves a photovoltaic plant (60 kWp), a battery energy storage system (237 kWh), and the demand from the marina including visiting boats (about 100 000 kWh/year). The system is connected to the public electricity supply. A baseline simulation indicates that 91 per cent of the energy from the photovoltaic plant is consumed internally (self-consumption); the rest is sold to the public grid. Without the battery, the self-consumption would be 52 per cent. The battery thus increases the supply of free, solar energy by 39 per cent of the annual PV production.

Introduction

The Ballen marina installed a large battery and a photovoltaic (PV) plant in 2019 to implement a *smart energy* system. On the supply side, the battery stores energy for use after sunset. On the demand side, some of the electrical loads on the marina can be deferred in time. For example, the onshore wastewater pump could be operated during the night, because the wastewater is held in a tank. Furthermore, since heat pumps link electricity with heat, the system is not just a *smart grid* system, but a smart *energy* system. The demonstrator is specified in overall terms in a report, which is a deliverable of the SMILE project [1]. A fact sheet summarises the specifications and the current performance [2].

If the project is a success, the system can be replicated in other marinas, for example among the 266 members of the association of marinas in Denmark [3]. Marinas consume more during the summer, which fits the production profile of a PV plant. Such a system may even become relevant for households or *smart houses*, because the prices on PV panels and batteries are dropping.

Figure 1 shows the components of the smart energy system marked on an aerial photograph. The battery energy storage system (BESS) is inside the so-called *Warehouse*. The photovoltaic panels are in three sites within the marina, namely: the roofs of The Warehouse and a service building taken together; the outer side of a board fence; and the two faces of the roof on the harbour master's office. The board fence is a barrier against the sea facing southeast, and the PV panels are mounted vertically on the seaward side.

The technical goal is to exploit the available solar energy as much as possible (maximize *self-supply*). Equivalently, to cover as much as possible of the marina's demand by solar energy (maximize *self-sufficiency*). The economic goal is to minimise the annual cost of operation. On the nontechnical side, the goal is to attract more sailors to the marina and ultimately to increase Samsø's population.

Figure 1. Overview of the Ballen marina with its smart energy components.

Data Description

The smart energy components were installed in 2019, and the data concern 2021. The data are collected in a spreadsheet (Excel, Ballen2021_hourly.xlsx). The paragraphs below explain the data column-by-column.

StartTime, EndTime

Date and time are in Excel format (dd/mm/yyyy hh:mm). This is practical for searches and lookup. The time is the local time (Central European Time / Central European Summer Time). In principle, only the clock changes to summertime / wintertime while the data collection continues with a sample period of one hour. The switch to/from summertime is marked in yellow (28 March and 31 October), note the time stamps.

Demand [kWh/h]

There is one public meter, which connects the marina to the public grid. Figure 2 shows a large peak in the summer period, when many boats visit the marina. The rest of the year the load is moderate. This is an advantage, because the PV panels perform their highest during the sailing season. During December, January, and February the production is about one tenth of the May production. On the other hand, the demand peak in July is so large that the PV panels and the battery cannot cover the demand. The remainder must come from the public grid.

PV [kWh/h]

The measurements are from 2021, and the source is the data in the dashboard (Xolta). A custom made tool (Xolta.Rm.Export) extracted the data from the cloud database. The column PV holds the raw data. In the accompanying simulation spreadsheet (Ballen2021_sim.xlsx), the real production in column PV includes an estimate of the additional production on the roof of the harbour master's office. This latter production was never measured in the PV electrical summation point in the distribution board, only locally by the inverter software. Therefore, the measured PV production is off by the amount coming from the harbour master's office. Also the consumption is off by the same amount, since it is calculated from the power balance, not measured. The harbour master's office production, measured by its inverter, is included as an additive percentage (6.6 per cent) in the sheet 'Parameters' (Ballen2021_sim.xlsx).

Spot [EUR/kWh, DKK/kWh]

The price of electricity follows the spot price on the Nord Pool electricity market. The prices are hourly prices on the so-called DK1 market, which is the western part of Denmark. The electricity selling price for the marina is the same as the spot market price. The buying price is the spot price plus taxes and fees. Nord Pool no longer supplies time series free of charge. Instead, the data were extracted from ENTSO-E[1].

Heat pump [kWh/h]

The Warehouse has a visitor room heated by a heat pump. A gadget (Smappee) measures its electricity consumption in the distribution board. The indoor temperature is not held constant, but mainly follows a schedule enforcing nightly temperature setback. Occupants sometimes override the schedule using the handheld remote control. But the heat pump falls back to the schedule at the start of the following time block in the schedule. The heated area is 30 square metres, and the walls and the roof lack insulation. The heat pump is a controllable load, which can be scheduled remotely via the Internet. Its annual electricity consumption was almost 1000 kWh in 2021. Comparing with the annual marina consumption of about 100 000 kWh gives an idea of its potential for shifting energy or saving energy. There are five heat pumps in all: one in the Warehouse, one in the harbour master's office, and three in the service building (for dehumidifying the shower room, not for heating).

[1] https://transparency.entsoe.eu/transmission-domain/r2/dayAheadPrices/show?name=&defaultValue=false&viewType=GRAPH&areaType=BZN&atch=false&dateTime.dateTime=19.06.2022+00:00

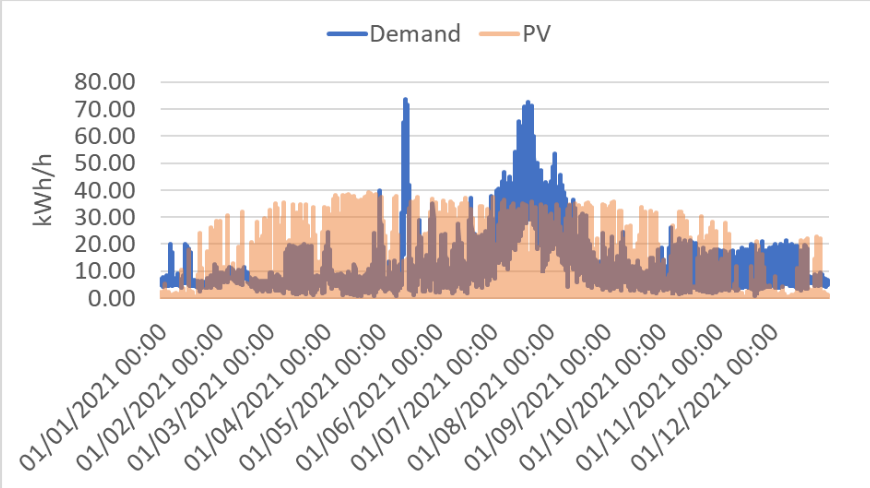

Figure 2. The electricity consumption of the marina with PV overlaid. Long weekends, popular with visiting sailors, can be recognised as well as the sauna (15 kW).

Baseline Simulation

The following rule shows the simplest possible strategy for controlling the battery.

IF PV power ≥ demand THEN

IF battery is not full THEN charge battery ELSE sell to grid;

ELSE

IF battery is not empty THEN discharge battery ELSE buy from grid.

Selling to the grid is to be avoided, because the selling price is low, and it is better to use the solar energy to maximize the self-supply. Buying from the grid is unavoidable, because the PV production is too small to cover the annual demand. The battery acts as a buffer, and this is the default mode of operation. It is called 'max self-consumption' in the battery management system.

Using the data set and the simple load-matching algorithm above, a baseline simulation is included in a separate file (Excel, Ballen2021_sim.xlsx). As a result, Figure 3 shows that 95 per cent of the PV production is used by the marina, the remainder spills over to the public grid. The marina is 43 per cent self-sufficient (renewable energy share) owing to its larger consumption compared to the PV production. The battery improves the use of the PV plant from 52 per cent to 95 per cent. On the marina side, the self-sufficiency increases from 25 per cent without the battery to 43 per cent with the battery.

Figure 4 explains why and when the PV plant, battery, and load are out of balance. During the peak season, all available PV supply is fully consumed by the marina, because the consumption is high. However, before the summer peak, the PV production saturates the battery occasionally. At those occasions it is necessary to spill the excess to the grid.

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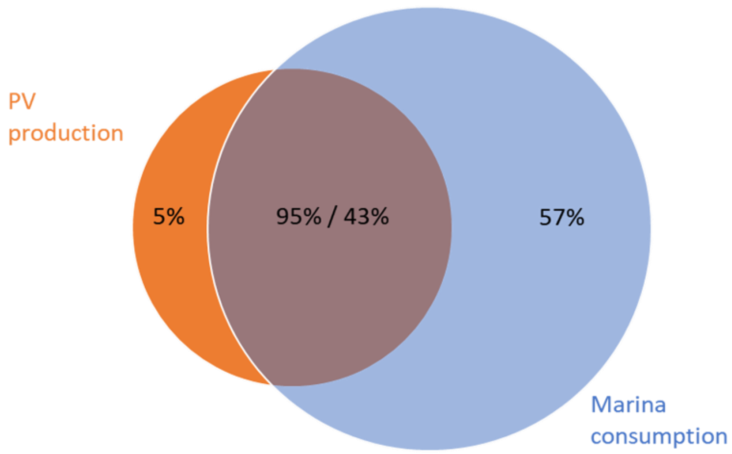

Figure 3. Performance in terms of energy (kWh).

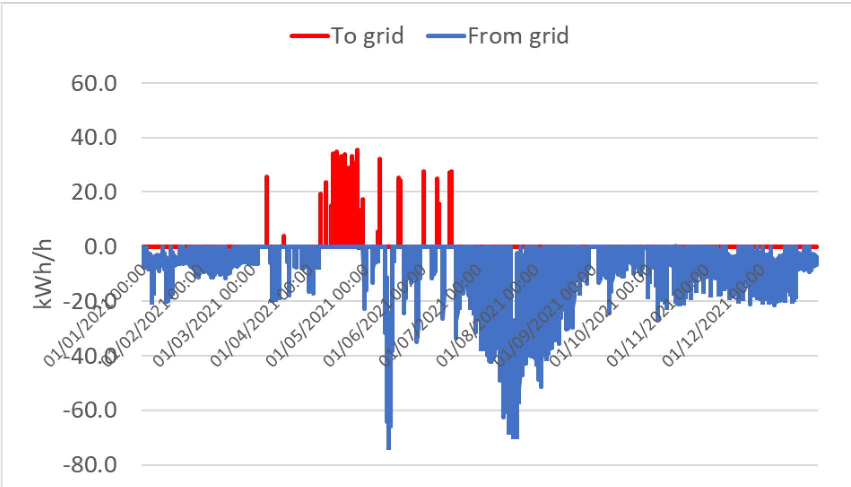

Figure 4. Export (up) and import (down) when using the battery as a buffer.

Smart Scheduler

The load profile (Figure 2) has a large peak during the summer, more than the battery plus the PV production can match. To smooth out peak consumption, some loads can be deferred. For example, the heat pumps can preheat or precool rooms, the sauna heater can preheat the cabin at times when the battery can sustain it, and the wastewater pump can start during the night. The loads are specified in a separate document, which also suggests some heuristic control rules [4].

It may be possible to affect the demand. The boats access up to 340 connection points, and a boat tariff could make electricity more expensive during peak hours and less expensive during the dark hours. This could help to smooth out the demand from the boats. However, it is unpopular; the sailors prefer simplicity and transparency – a hassle-free visit.

More realistically, the battery can be precharged at times when the price is low. Nord Pool publishes the day-ahead spot prices at 14:00 every day. A scheduler could use the price information to make decisions daily.

Conclusion

The data set is a call for scheduling algorithms. A smart scheduling algorithm could calculate the best timing to turn flexible loads on or off, by means of *linear programming*, for instance. The objective is to maximize the self-supply or, more importantly, to minimize the annual operational cost.

The baseline simulation shows that the improvement in terms of energy can be at most 5 per cent, ideally (from 95 per cent self-supply up to 100 per cent). This may seem to be a small improvement, but every percentage counts when an alternative investment may yield less than one percent or even negative interest.

Acknowledgement

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[2] https://h2020smile.eu/